Athos I Oil Spill

Restoration Scaling Paper for Tributary Injuries:

Dam Removal and Riparian/In-stream Habitat Restoration on Darby Creek

and

Habitat Restoration at John Heinz National Wildlife Restoration

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Prepared By:

Dr. Ann Shellenbarger Jones
Industrial Economics, Incorporated

Michael Donlan
Industrial Economics, Incorporated

Introduction

The Trustees determined that approximately 1,899 acres of tributary habitat - shorelines, extensive wetlands, intertidal flats, and shallow benthic habitats - were injured by the *Athos* oil spill, quantified as a spill-related resource loss of approximately 524 discounted service acre years (DSAYs) (Shoreline TWG, 2006). To compensate for this loss, the Trustees propose two restoration projects in southeastern Pennsylvania (Figure 1). The first is removal of three dams and a remnant bridge pier from Darby Creek in southeastern Pennsylvania, resulting in the opening of an additional 2.6 miles of the creek to anadromous fish, and to complete riparian and in-stream restoration projects along nearly ten acres of the creek edges. This low-risk restoration approach will be implemented in a tributary to the Delaware River, which enters the Delaware at Tinicum Island close to the spill site, and is consistent with existing federal, state, and local restoration goals for the Delaware River. The second project will be undertaken at John Heinz National Wildlife Refuge (NWR), located near the mouth of Darby Creek, and will create a series of tidally-connected channels, shallow pools and fringing wetlands functionally similar to tributary habitat. The area is currently an unproductive portion of the Refuge covered by mats of chemically treated *Phragmites australis* that range in thickness from several inches to greater than 12 inches.

Project Description

The first proposed compensatory restoration project for tributary injury is a dam and remnant pier removal and stream restoration project on Darby Creek in southeastern Pennsylvania. The creek currently has three low dams and a remnant bridge pier that interfere with stream flow and the movement of anadromous fish (Table 1).[1] The project will remove the four obstructions and implement in-stream and riparian restoration for up to 1,000 feet upstream and downstream of the current obstructions.

Dam removal is expected to restore normal stream channel flows and facilitate passage of anadromous fish. No anadromous fish were noted in a survey of sites upstream of the dams, while the catadromous American eel was present (PFBC 1986). Downstream of the first dam, a variety of anadromous fish are found, including alewife, striped bass, and shad (NOAA 2003). Riparian restoration and enhancement will improve the general health of the creek. Overall, approximately 60 percent of the riparian buffer within the Darby Creek watershed is estimated to have been lost (DCVA 2004). The lower reaches of Darby Creek (downstream of the dams, near the mouth of the river) include extensive freshwater wetlands, including the John Heinz National Wildlife Refuge.

[1] The remnant bridge pier is the remainder of a collapsed bridge. The steel and concrete rubble interferes with sediment transport and creates debris jams, which caused localized flooding, leading to damages to riparian habitat.

Figure 1

Location of Proposed Restoration Projects for Tributary Injuries

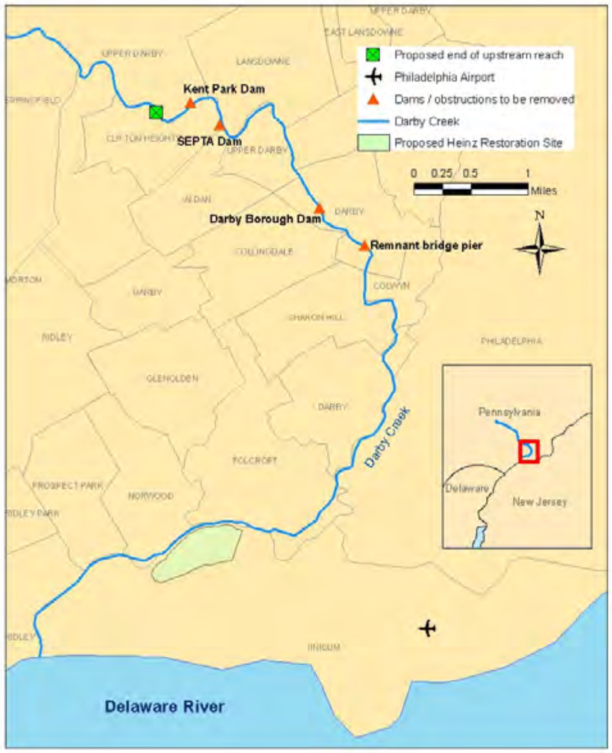


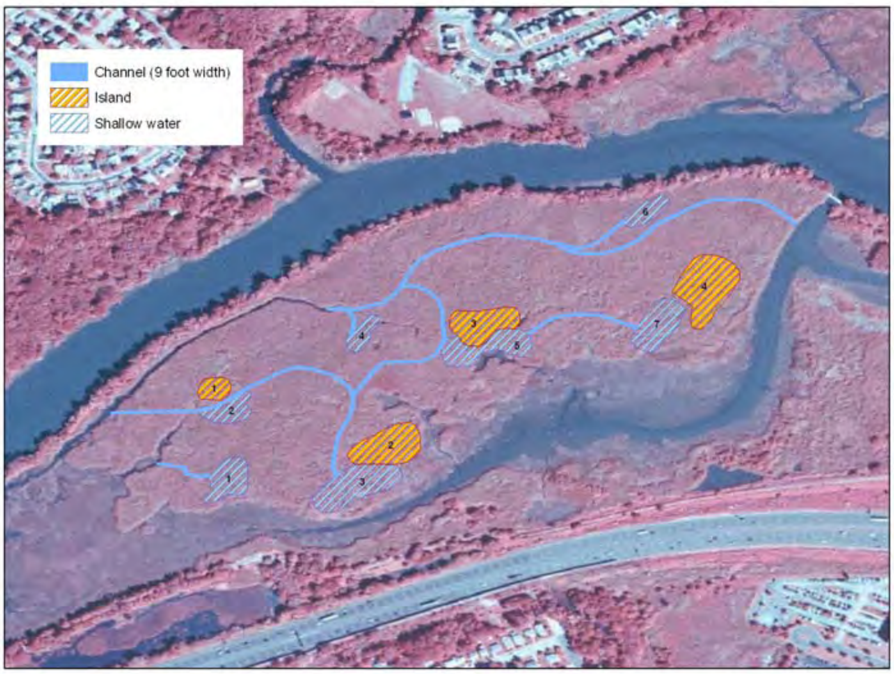
Table 1 **Description and Location of Darby Creek Obstructions**			
Obstruction	**Location (River Mile)**	**Owner**	**Height (feet)**
Remnant bridge pier	7.31		n/a
Dam 1: Darby Borough	7.91	Borough of Darby	6
Dam 2: SEPTA	9.63	SEPTA[a]	4
Dam 3: Kent Park	10.1	Delaware County	6
End of Reopened Stream Reaches[b]	10.51		

a. Ownership of SEPTA dam is historically uncertain, but the Pennsylvania Department of Environmental Protection (PADEP) is satisfied that Lansdowne Borough will take responsibility. The dam will hereafter be referred to as SEPTA dam.
b. An additional dam is located at RM 10.51. No plans to remove this obstruction exist at this time.

The second restoration project will be implemented at John Heinz NWR. The Henderson Dike Area (FL-4, see Figure 2) at John Heinz NWR was historically a freshwater tidal wetland, but was used as a dredge material disposal site by the Army Corps of Engineers (ACOE) until the mid-1960s. Recent mitigation projects within FL-4 have begun to return the area to its tidal wetland status: the Blue Route Mitigation Site (1992) and the Philadelphia International Airport Mitigation Site (1996). Both of these projects involved the removal of organic fill and the restoration of tidal exchange. The remaining unrestored area on-site comprises 56 acres and contains approximately 2-4 feet of fill. This area is currently minimally affected by tidal influence and is dominated by an invasive plant species, *Phragmites*, which severely limits its habitat value for wildlife. The results of a 2007 site visit indicate that the majority of the site is characterized by *Phragmites australis* that has been chemically treated. Cane mats cover the soil surfaces which range in thickness from several inches to greater than 12 inches. Where the cane mats are thinnest, *Typha latifolia*, *Pontederia cordata*, and *Sagittaria latifolia*, are colonizing the soils. The subject area does not appear to have a significant tidal interface on normal tide cycles thereby limiting the ability of the wetland to provide refugia or reproductive habitat for fish or benthic organisms.

Figure 2

Map and Conceptual Plan for Heinz NWR Restoration Project



As shown in Figure 2, the project will involve excavation of a series of channels and pools. This proposed 7-acre area of channels and pools will create functional tributary habitat, providing the ecological services lost due to tributary injuries. Tributary services include providing nursery habitat for fish, potential nesting sites for reptiles and waterfowl, and roosting sites for wading birds. The channels will restore tidal flow to the area and allow wild rice seed to be transported into the wetland interior with the tide. Indirect benefits to the remainder of the 56-acre parcel will result from occasional flooding/flushing during storm surges and/or other high tidal events, leading to modest ecological improvements throughout the entire site. The channels will also provide habitat for anadromous fish species. Depending on results from a feasibility analysis, the dike may also be breached to increase tidal exchange. While flooding as a result of increased tidal exchange will potentially lead to decreased stands of *Phragmites*, the affected areas will still require periodic treatment into the future. The excavation process will generate spoil; the Trustees intend to place the material adjacent to the pools to form islands of saturated scrub/shrub wetlands. In the event that feasibility studies or the permitting process indicate this is not suitable, the Trustees intend to utilize off-site disposal.

Restoration Objectives

The objective of this restoration project is to provide 524 DSAYs of ecological benefit to tributary resources. Dam removal will allow use by anadromous fish, similar to those found in un-dammed reaches injured by the Athos I oil spill. Restoration of normal stream channels through removal of the dams and remnant bridge pier also will enhance sediment transport and reduce sediment deposition, providing ecosystem enhancement. Riparian and in-stream habitat projects will improve habitat for diamondback terrapins, wading birds and shorebirds, and other fauna that make use of shoreline habitat (Shoreline TWG 2006). Marsh restoration will restore habitat similar to the tributary wetlands and intertidal habitat injured in the spill.

Scaling Approach

The Trustees quantified a spill-related tributary resource loss of approximately 524 DSAYs (Shoreline TWG 2006). Approximately 1,899 acres of shorelines, extensive wetlands, intertidal flats, and shallow benthic habitats in six tributaries in New Jersey were oiled and injured as a result of the spill. For injury determination, the oiled tributaries were treated as an entire system encompassing open water, shoreline habitats (*i.e.* isolated wetlands), wetland fringe along the shoreline, and associated tidal flats. The majority of tributaries were lightly oiled (1,216 acres). The injury to tributaries is scaled to a stream restoration project in Darby Creek and to a habitat restoration at John Heinz NWR. As described in more detail below the Darby Creek restoration project is expected to generate approximately 281 DSAYs of tributary ecological benefit, and the NWR restoration project is expected to generate approximately 228 DSAYs of tributary ecological benefit. The two projects identified by the Trustees as appropriate for addressing tributary injuries will provide approximately 509 DSAYs.

Darby Creek Dam Removal

The first proposed restoration project includes dam removal and riparian/in-stream restoration in Darby Creek. Dam removal in Darby Creek will result in increases in anadromous fish, particularly the American shad, as well as likely improvements in vegetation and macroinvertebrates and a decrease in localized flooding near dams during high water events. While not interfering with the movement of migratory fish, the remnant bridge pier interferes with stream flow and causes flooding events; its removal is essential in order to realize the in-stream ecological improvements from dam removal.[2] General habitat improvements from the removal of the four obstructions will include an increase in occasionally inundated riparian areas (*i.e.* an increase in fringing wetland) in upstream areas (Shafroth *et al.* 2002). Species shifts in macroinvertebrates and fish species from lentic (slow water) to lotic (moving water) are also generally observed in the former impoundments upstream of small dams (Hart *et al.* 2002).

[2] Personal communication, Sara Deuling, American Rivers, October 23, 2007.

Recent research on the effects of small dam removal has resulted in several models of ecosystem improvements (Doyle *et al.* 2005). Doyle *et al.* (2005) synthesized several small dam removal studies in Wisconsin to examine how the physical effects of dam removal (*e.g.*. changes in channel form, habitat type) affected riparian vegetation, fish, macroinvertebrates, and nutrient dynamics.[3] Different components of the ecosystem recover at different rates. Riparian vegetation appeared to require the greatest time to reach a new equilibrium, while macroinvertebrates had the shortest time.

To evaluate the effect of dam removal on fish communities, Doyle *et al.* (2005) uses habitat index values to estimate the relative value of habitat following dam removal. The index uses quantitative habitat characteristics such as riffle occurrence, cover for fish, and substrate type to value habitat on a 100-point scale in regions upstream and downstream of a small dam removal (Kanehl *et al.* 1997). In areas upstream of the dam removal, particularly in the impounded area, a significant improvement over a five-year period was found in habitat value (increase of 40 percentage points in the first mile, 55 percentage points in the next half mile, and 10 percentage points for the following half mile, Table 2).[4] The first two reaches are representative of impounded areas, while the third reach upstream represents habitat upstream of the impoundment. While only a small reach downstream of the dam was evaluated (0.8 miles), an increase of fifteen percentage points was found in that area (Doyle *et al.* 2005).

Table 2

Increase in Habitat Index Values Five Years After Dam Removal

	0-0.8 miles downstream	**0-1 mile upstream**	**1-1.5 miles upstream**	**1.5-2.1 miles upstream**
Habitat Index Increase over Five Years	15	40	55	10

Habitat Index values are based on a 100-point scale. Source: Doyle *et al.* 2005

Corresponding to the increase in habitat value, an increase in smallmouth bass was seen (Doyle *et al.* 2005). Smallmouth bass, in addition to their desirability to anglers, are indicative of

[3] While the dams studied in the paper are located in Wisconsin, the Trustees expect similar responses in Pennsylvania due to similarities in dam type and age and stream width. Those reviewed in Doyle *et al.* (2005) are also century-old dams on small channels with declining structural integrity. Impoundments are reasonably small but have silted in considerably over the past hundred years. Widths were similar, with 30-130 ft for the Darby Creek and 40-90 ft in Wisconsin. The most significant difference in the potential dam removal projects is the prevalence of mussels in the Wisconsin waterways, which can be detrimentally affected by dam removal. Mussels are not prevalent in the Darby Creek. Similar dam removal projects have been undertaken by the Pennsylvania Fish and Boat Commission (PFBC) and other federal, state, and non-profit organizations in Pennsylvania (*e.g.* Wyomissing Creek, Schuylkill River, Conestoga River). These projects demonstrate significant improvements to biotic communities and stream flow, although not providing a quantitative estimate of ecological improvement. Return of anadromous fish (Conestoga, Schuylkill), improvements in growth and survival of wild or stocked fish (Wyomissing, Conestoga), and increases in macroinvertebrate diversity and abundance (Conestoga) have all been noted (PFBC 2007).

[4] The current impoundments on Darby Creek may not extend to 1.5 miles upstream of the obstructions; however, benefits in the third category (1.5 to 2.1 miles upstream) are representative of improvements to the habitat index above the impoundments. Additionally, substantial benefits were recorded for fish (a greater than 10 times increase in biomass for the indicator species, smallmouth bass) in the area above the impoundment (Kanehl *et al.* 1997). Therefore, we maintain the same distances and improvements used in Doyle *et al.* (2005).

good habitat and water quality. Common carp, a "ubiquitous and destructive non-native species" found in the impounded area upstream of the dam, decreased in biomass immediately after dam removal. Removal of the dam resulted in rapid geomorphic changes in the impoundment, including increased sediment size and fish cover (Doyle *et al.* 2005).

Using information on vegetation, fish communities, and other characteristics, Doyle *et al.* developed two recovery curve models, driven by the sensitivity of particular resident organisms and the characteristics of the dam to be removed (Doyle *et al.* 2005). Given the low profile and partially breached conditions of the three dams on Darby Creek, as well as the planned riparian and in-stream restoration, a nearly full recovery from impacts of the dam would be expected. Recovery of anadromous fish such as shad is expected to happen very quickly in Darby Creek, due to on-going state programs to stock shad. Some communities, such as benthic macroinvertebrate and non-migratory fish, may show initial declines due to habitat disruption, but generally recover quickly and show significant improvements over pre-dam removal conditions within a few years. Due to the riparian and in-stream restoration planned for Darby Creek, ecological improvements in vegetation are expected to occur quickly.

For scaling purposes, we apply the habitat index improvements found in Doyle *et al.* (2005) following dam removal (Table 2) to the Darby Creek restoration project. An improvement of 40 percentage points (based on a maximum habitat value of 100 percent) is applied to the first mile upstream of each dam. From 1 to 1.5 miles, an ecological improvement of 55 percentage points is assigned and from 1.5 to 2.1 miles, an ecological improvement of 10 percentage points is assigned (Table 3).[5] Downstream of the first dam removal, an improvement of 15 percentage points is used for the first 0.8 miles. Given the limit of downstream data available in Doyle *et al.* 2005, for the next two 0.8 mile segments downstream, improvements of 10 and 5 percentage points, respectively, are assigned.[6]

The Habitat Equivalency Analysis (HEA) method was used to determine the scope of restoration necessary to compensate for the losses resulting from the spill (NOAA, 1999). HEA is a resource-to-resource scaling method to determine compensation for lost services based on the quantification of incident-related natural resources injuries. HEA considers several project-specific factors in scaling restoration, including elapsed time from the onset of injury to restoration implementation, relative productivity of restored habitats (that is, the proportional equivalence of ecological services provided by the compensatory restoration project relative to the baseline productivity of the injured habitat), the time required for restored habitats to reach full function, and project lifespan.

[5] The largest segment upstream of a dam removal on Darby Creek is 1.7 miles between the first and second dams; therefore, no estimate is made for improvements beyond the "1.5 to 2.1 mile" category.

[6] These improvements downstream of the first dam will include any improvements as a result of removing the remnant bridge pier, located at river mile 7.31, 0.6 miles downstream of the first dam. Additionally, unquantified benefits may occur at a low level along the whole downriver stretch.

Table 3

Characteristics and ecological benefits for each segment of Darby Creek

Segment Name	Segment Length (miles)[a]	Average Width of Segment (feet)[b]	In-stream Area[c] (acres)	Ecological Uplift (percent)	DSAYs[d]
Delaware River to Dam 1[e] (uplift assumed for 2.4 of the 7.91 miles downstream of Dam 1)	Reach 1: 0.8 Reach 2: 0.8 Reach 3: 0.8	38 38 38	3.7 3.7 3.7	15 10 5	16.4 10.9 5.5
Dam 1 to Dam 2	Reach 1: 1	38	4.6	40	54.6
	Reach 2: 0.5	38	2.3	55	37.5
	Reach 3: 0.2	38	1.0	10	3.0
Dam 2 to Dam 3	0.47	35	2.0	40	23.6
Dam 3 to end of anadromous system (upstream blockage)	0.41	29	1.4	40	17.1
Total	**4.98**		**49.2**		**168.7**

a. Segment length is divided into reaches for the two segments that are long enough to have different ecological uplift in different portions. Division is based on the lengths described in the paragraphs above and in Table 19.
b. Estimates of average segment width are from David Kristine, PFBC. The estimates are based on average widths (10 measurements between each dam/obstruction) through aerial photo interpretation.
c. In-stream acreage is calculated as segment length (in feet, as miles*5280 feet per mile) multiplied by average segment width (feet), divided by 43,560 square feet per acre.
d. Parameters for DSAY calculations are presented in Attachment 1.
e. The removal of the remnant bridge pier will take place in this segment. However, the abutment does not provide a complete barrier to fish passage or sediment transport, so is not included as a dam removal for ecological benefit purposes. However, it is taken into account in the benefits accrued downstream of Dam 1. Riparian restoration at the remnant bridge pier is considered under the benefits in Table 4.

To determine the estimates for the HEA input parameters identified above, we relied on resource agency staff experience with creating wetlands in this region, data from other dam removals in Pennsylvania, and information in the scientific literature. We assume that the dam removal will take place in 2009. Linear improvements to the levels described above and shown in Tables 2 and 3 are assumed to occur over a five-year period following project implementation.[7] Benefits are assumed to accrue in perpetuity. Based on these inputs and using the three percent annual discount rate typically applied in HEA calculations, an acre of streambed with a five percent uplift would provide a credit of 1.48 DSAYs.[8] Values for each stream reach, reflecting reach length, width, and ecological uplift, are show in Table 3 (see Attachment 1 for detailed calculations). Overall, removal of the three dams is expected to provide a credit of 169 DSAYs.

In-stream restoration and riparian buffer enhancement will provide additional ecological benefits. As described above, a portion of the Athos spill-related injuries occurred in shoreline and wetlands areas along the six affected tributaries. Dam removal will naturally enhance these

[7] Based on Doyle *et al.* (2005), the Trustees presume that most habitat improvements occur within one to five years.

[8] Five percent is used as a basis for calculations. Therefore, a one acre area with ten percent uplift would provide 2.96 DSAYs (2 * 1.48).

areas due to creation of wetlands and reductions in extreme flooding events (Shafroth *et al.* 2002). Additionally, riparian and in-stream restoration will take place in the vicinity of the dams and remnant bridge pier after removal. Based on available estimates for the project, the expected restoration/ enhancement area is approximately 9.5 acres (Table 4). While detailed project plans have not yet been developed, past work in similar removal/restoration efforts has included stream bank stabilization, riparian vegetation, and in-stream vegetation. For restoration scaling purposes, uplift assumptions applied to the riparian buffer projects are similar to those used for in-stream habitats. In this way, the tributary system is considered as a whole for both injury and scaling purposes (*i.e.* shallow benthic habitats, intermittently exposed areas, and shoreline are all included together).[9]

For each site, an ecological uplift at the lower end of the dam removal benefits adjacent to the dam is assumed due to the limited nature of the projects (40 percent). Overall, the 9.5 acres of buffer restoration would provide roughly 112 DSAYs (Table 4). The combination of in-stream and riparian restoration (112 DSAYs) with the calculated benefits for dam removal on Darby Creek (169 DSAYs, Table 3) will provide approximately 281 DSAYs of ecological benefit.

Table 4

Ecological uplift approximations for riparian buffer enhancement.

Site	Approximate Buffer Length (feet)[a]	Approximate Buffer Width (feet)[a]	Buffer Area[b] (acres)	Ecological Uplift (percent)	DSAYs[c]
Remnant bridge pier	132	38	0.1	40	1.4
Dam 1: Darby Borough	716	322	5.3	40	62.8
Dam 2: SEPTA	963	57	1.3	40	14.9
Dam 3: Kent Park	1077	113	2.8	40	33.1
Total			**9.5**		**112.2**

a. Riparian buffer lengths and widths were provided by David Kristine, PFBC. Values were determined in the vicinity of the dams only and based on results from past projects.
b. Buffer area is calculated as buffer length (in feet) times the buffer width (in feet) divided by 43,560 square feet per acre.
c. DSAY calculations are described in Attachment 1.

John Heinz NWR Habitat Restoration

The scaling approach for NWR habitat restoration includes two components: 1) the calculation of ecological benefits (measured in DSAYs) directly resulting from the creation of tidally-connected channel and pool habitat; and 2) the calculation of (relatively modest) indirect benefits to the remainder of the site resulting from occasional flooding/flushing during storm surges and/or other high tidal events. These calculations are summarized below.

[9] The majority of the acreage in restoration/enhancement will be in riparian areas, rather than within the streambed. Therefore, the Trustees assume complete coverage of all riparian buffer areas and do not estimate in-stream acreage.

Final project design will reflect the results of a detailed feasibility study to be undertaken in the future. However, a planning-level design (documented in Figure 2) has been developed by the Trustees based on site visits, site-specific technical data, and consideration of various restoration design alternatives. This design would result in the creation of approximately 4.5 acres of shallow pools, 1.2 acres of channels, and 1.3 acres of channel buffer habitat.[10] For scaling purposes, this will result in restoration of approximately 7.0 acres of restored habitat that is expected to be functionally similar to tributary habitat. This approach is consistent with Trustee tributary injury calculations, which combined tributary subtidal, intertidal, and a small width of adjacent shoreline acreage into a total acreage of injured "tributary habitat."

Scaling calculations for the 7.0 acres that will directly benefit from restoration activities assume an ecological uplift of 70% (*i.e.*, that the targeted area currently contributes minimal productivity, and after restoration activities will become functional tributary habitat). This assumption reflects the fact that much of the site is currently covered by a relatively thick mat (several inches to greater than 12 inches) of *Phragmites australis* that has been chemically treated. The site has been in this condition for several years, and is not expected to change appreciably due to a lack of tidal flushing. This mat will be removed in excavated channel and pool areas, and elevations will be lowered sufficiently to turn these 7.0 acres into high functioning, tributary-like habitat.[11] A rapid improvement in ecological services is expected for the Heinz project following the physical creation of channels and ponds. Similar to improvements following dam removal, we anticipate rapid improvement in the first few years following project implementation. For benefit calculations, a linear improvement in the first three years is used. Baseline ecological services for the site as tributary habitat are estimated at 10 percent. Following restoration, we estimate maximum ecological services of 80 percent. Restoration is assumed to begin in 2009, and provide a 23% uplift in 2009, a 47% uplift in 2010 and 70% uplift in 2011 (and future years). Restoration benefits are summed through 2058, reflecting the expectation that ecological benefits are likely to be sustained for several decades. Consistent with standard practice in scaling calculations, future benefits are discounted at an annual rate of three percent. Based on these parameters, the "direct" benefits of creating approximately 7.0 acres of channel and shallow pool habitat total approximately 114 DSAYs (see Attachment 2 for detailed calculations).

Scaling calculations also include "indirect" benefits expected to accrue to the remaining 49 acres at the site. Creation of tidally-connected channels and shallow pools throughout the site will occasionally expose this larger area to tidal inundation during storm surges and/or other high tide events. The areas surrounding the channels and ponds will experience increased flooding and seed distribution, resulting in general improvements to the tributary services provided by the area. Areas closest to the channels may experience significant improvements, possibly doubling in service levels, but improvements will lessen with distance from the channelizations. Due to the uncertain nature of the coverage of the improvements, a general uplift of 10 percent is used

[10] For scaling purposes, ecological benefits of channel creation are assumed to extend five feet to either side of the excavated channel. This approach is consistent with tributary injury calculations, which included five feet of shoreline on both sides of injured tributaries.

[11] Estimates of improvements in ecological services at John Heinz NWR are based on professional judgement, discussions with USFWS staff, and current and proposed site parameters.

for the entire parcel surrounding the new channels and ponds. More specifically, scaling calculations assume a three percent uplift in 2009, a seven percent uplift in 2010 and a 10 percent uplift in 2011 (and future years). Benefits are summed through 2058 and discounted at an annual rate of three percent, consistent with scaling calculations for the 7.0 site acres proposed for excavation. Based on these parameters, the "indirect" benefits of the proposed project to the remaining 49 site acres total approximately 114 DSAYs (see Attachment 3 for detailed calculations).

Probability of Success

Dam removals are frequently undertaken in Pennsylvania. Since 2000, the Pennsylvania Fish and Boat Commission (PFBC), Pennsylvania Department of Environmental Protection (PADEP), American Rivers, USFWS, NOAA, and other partners have implemented the removal of 15 dams and currently have over 35 active dam removal projects in the Delaware Basin. All three dams proposed for this project are currently owned by public entities (Borough of Darby, Southeastern Pennsylvania Transportation Association (SEPTA), or Delaware County). The PFBC has maintained an extensive hatchery program for American shad over the last twenty years and now includes hickory shad as well, and has stocked millions of fry into the Delaware River/Estuary watershed. Given the extensive experience that PFBC, American Rivers, and other agencies have in the area with dam removal and fish re-introduction, we believe that this project has a high likelihood of success.

The Trustees note that several sites on Darby Creek in the area of the dams proposed for removal were listed as impaired by the Philadelphia Water Department. The lower Darby Creek near the John Heinz NWR was not evaluated. Recent macroinvertebrate studies indicated that pollution-tolerant species dominate the macroinvertebrate communities near the dam sites (PWD 2004). However, fish surveys near the same locations indicate the presence of a number of species including sunfishes, brown and yellow bullhead trout, and smallmouth bass.[12]

The John Heinz NWR project is located within a previously established national wildlife refuge. Similar projects have already been undertaken within the refuge and have met with success. The restoration approach (*i.e.*, excavation of channels and pools) is straightforward, and highly likely to be implemented successfully and substantially improve ecological conditions at the site through removal of thick mats of dead *Phragmites* and improvements in tidal connectivity across the site.

Performance Measures and Monitoring

For the dam removal project, project performance will be assessed based on changes in physical habitat, fish assemblages and numbers, and macro invertebrate populations. Monitoring for these parameters will be conducted before removal and at one-year intervals for the first three years following completion of the project. The protocols for monitoring will be based on EPA standards and tailored to be site-specific. Completion of this monitoring program will indicate whether the project goals and objectives have been achieved, and whether corrective actions are required to meet the goals and objectives.

[12] Personal communication, David Kristine, PFBC, February 12, 2007.

In the event that performance standards are not achieved or monitoring suggests unsatisfactory progress toward meeting established performance standards, corrective actions will be implemented. Possible corrective actions include regrading of riparian fringes and replanting of appropriate vegetation. These corrective actions, if needed, will be funded by the contingency component of the project costs (Table 5).

For the habitat restoration at John Heinz NWR, project performance will be assessed through both construction performance and vegetation performance. Channel/pond area, flow, and depth will be measured, to ensure that they are sufficient for tidal exchange. Buffer plantings will be monitored to ensure biodiversity and plant survival. Restored habitats will be monitored once a year at the end of the growing period for five full growing seasons. Monitoring assessments will include documentation of hydrologic regime, soil characteristics, plant species present and confirmation of planned site grading and elevation. At the end of the monitoring period, a survival rate of 85 percent of planted vegetation (and/or similar native vegetation) should be documented; less than 25 percent of plant species should be characterized as non-native, invasive, or noxious. If the area contains greater than 25 percent non-native, invasive, or noxious plant species, the area will be treated and a second monitoring period will be conducted to determine the effectiveness of the action. Any corrective actions will be funded by the contingency component of the project costs (Table 6).

Approximate Project Costs

Table 5 provides a summary of expected costs for removing three dams and one remnant bridge pier from Darby Creek and restoring 9.5 acres of riparian edge and in-stream habitat to compensate for injuries to tributaries. The Trustees have determined dam removal and riparian restoration cost estimates based in part on preliminary plans developed by American Rivers. Monitoring costs include PFBC staff time, equipment use, and subcontractor identification of macroinvertebrate species

Table 5

Summary of project costs: Darby Creek Dam removal and riparian/in-stream restoration

Cost Element	Total
Project Implementation	
Design and Contractual Assessment	$47,000
Removal of 3 dams and remnant bridge pier and riparian restoration	$286,000
Technical Oversight	$34,400
Monitoring	$30,000
Contingency (25 percent)	$99,350
TOTAL	$496,751

Table 6 presents estimated project costs for the improvement of 56 acres at John Heinz NWR. USFWS has prepared a detailed cost estimate for the project, based on considerable past experience in wetlands restoration on NWRs. In the event that the feasibility study or permitting process indicates that on-site disposal is not allowable based on contamination, hydrology, or other concerns, a disposal contingency is included, in addition to the standard project contingency amount. The disposal contingency amount is equal to the estimated increase in project costs if off-site disposal is required.

Table 6

Summary of project costs: Habitat Restoration at John Heinz NWR

Cost Element	Total
Feasibility and Design	$260,000
Project Implementation	
Channel Excavation	
Shallow Pool Excavation	
On-site spoil disposal	$1,906,835
Equipment	
Subtotal	
Monitoring	$207,400
Technical Oversight	$116,957
Contingency (25 percent)	$622,798
TOTAL	$3,113,990
Disposal Contingency[a]	$1,250,000

a. A disposal contingency has been added in case the feasibility study or permitting process indicates that on-site disposal is not allowable based on contamination, hydrology, or other concerns.

Environmental and Socio-Economics Impacts

Benefits to fishing and overall ecological health of the creek are expected from dam removal and riparian/in-stream restoration. Upper Darby Creek (above the obstructions described in this document) is currently stocked with rainbow trout and is regularly fished. Opening up of the creek would enhance spawning and holding habitat for resident fishes and add additional highly desirable migratory fish, as well as improve public access. The project is intended to restore connectivity of habitat and improve habitat quality in and along Darby Creek, as well as to involve and educate citizens about the watershed through educational outreach and restoration work.

Marshes are widely recognized as providing numerous ecological functions, including habitat for juvenile fish and shellfish, exporting detritus (energy source for the aquatic food web) into the estuary, and increasing water quality by filtering sediments and other pollutants from the water column. Marshes also provide many additional benefits such as storm surge protection, habitat for birds and mammals, and enhanced recreational use of the area by increasing the numbers of important aquatic species.

Restoring marsh habitat within the John Heinz NWR is not expected to have any significant adverse environmental impacts. Any impacts to existing habitats from project construction are expected to be temporary. Because lands intended for restoration already are government-owned, the Trustees do not expect the project to have any significant adverse economic impacts.

Evaluation

The Darby Creek dam removal project is consistent with the Trustees' evaluation criteria. It is cost-effective and restores the same type of habitat as that injured in tributaries in the same geographic area of the spill. Dam removal and tributary enhancement projects are also consistent with state, federal, and local restoration goals established for the upper estuary watershed of the Delaware River Basin. The project addresses objectives defined in conservation plans by both the Darby Creek Valley Association and the Delaware Estuary Program.

The marsh restoration project at John Heinz NWR is consistent with the Trustees' evaluation criteria. It is cost-effective and restores same or similar types of injury (*i.e.*, wetland/intertidal habitat loss on tributaries) in the same geographic area of the spill. Marsh restoration and enhancement are also consistent with state, federal, and local restoration goals established for the Delaware River and for the John Heinz NWR.

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Attachment 1

HEA Inputs and Results for Tributary Restoration Via Dam Removal and Riparian Restoration

Inputs:

Years to full service	5
Curve for Service Gain	Linear
Project life span[1]	In perpetuity
Discount Rate	3 percent

Calculations:

Discounted Ecological Service[2] = Ecological Service*[(1+Discount Rate)^(2006-Year)]

Results:

1 acre of tributary habitat with 100 percent ecological improvement provides 29.64 DSAYs
1 acre of tributary habitat with 5 percent ecological improvement provides 1.48 DSAYs

Annual Calculations (First 50 years):

Year	Ecological Service Improvement (per acre)	Discounted Ecological Service (per acre)	Year	Ecological Service Improvement (per acre)	Discounted Ecological Service (per acre)
2009	0.20	0.18	2034	1.00	0.44
2010	0.40	0.36	2035	1.00	0.42
2011	0.60	0.52	2036	1.00	0.41
2012	0.80	0.67	2037	1.00	0.40
2013	1.00	0.81	2038	1.00	0.39
2014	1.00	0.79	2039	1.00	0.38
2015	1.00	0.77	2040	1.00	0.37
2016	1.00	0.74	2041	1.00	0.36
2017	1.00	0.72	2042	1.00	0.35
2018	1.00	0.70	2043	1.00	0.33
2019	1.00	0.68	2044	1.00	0.33
2020	1.00	0.66	2045	1.00	0.32
2021	1.00	0.64	2046	1.00	0.31
2022	1.00	0.62	2047	1.00	0.30
2023	1.00	0.61	2048	1.00	0.29
2024	1.00	0.59	2049	1.00	0.28
2025	1.00	0.57	2050	1.00	0.27
2026	1.00	0.55	2051	1.00	0.26
2027	1.00	0.54	2052	1.00	0.26
2028	1.00	0.52	2053	1.00	0.25
2029	1.00	0.51	2054	1.00	0.24
2030	1.00	0.49	2055	1.00	0.23
2031	1.00	0.48	2056	1.00	0.23
2032	1.00	0.46	2057	1.00	0.22
2033	1.00	0.45	2058	1.00	0.22
				Total (2009-2058):	**29.64**

1. Ecological benefit is calculated for 500 years, which provides benefits in perpetuity based on the number of significant figures used in these calculations.
2. Values are discounted to 2006, the year for which injury DSAYs are calculated.

Attachment 2

HEA Inputs and Results for "Direct" Marsh/Channel Restoration (John Heinz NEW)

Inputs:

Project Implementation	2009
Maximum Ecological Service	85 percent
Years to maximum service	15
Curve for Service Gain	Logistic
Project life span	50
Discount Rate[1]	3 percent

Results:

1 acre restored marsh provides 15.56DSAYs of ecological service.

Annual Calculations:

Year	Ecological Service Improvement (per acre)	Discounted Ecological Service (per acre)	Year	Ecological Service Improvement (per acre)	Discounted Ecological Service (per acre)
2009	23%	0.21	2034	70%	0.30
2010	47%	0.41	2035	70%	0.30
2011	70%	0.60	2036	70%	0.29
2012	70%	0.58	2037	70%	0.28
2013	70%	0.57	2038	70%	0.27
2014	70%	0.55	2039	70%	0.26
2015	70%	0.53	2040	70%	0.25
2016	70%	0.52	2041	70%	0.25
2017	70%	0.50	2042	70%	0.24
2018	70%	0.49	2043	70%	0.23
2019	70%	0.47	2044	70%	0.23
2020	70%	0.46	2045	70%	0.22
2021	70%	0.45	2046	70%	0.21
2022	70%	0.43	2047	70%	0.21
2023	70%	0.42	2048	70%	0.20
2024	70%	0.41	2049	70%	0.20
2025	70%	0.40	2050	70%	0.19
2026	70%	0.38	2051	70%	0.18
2027	70%	0.37	2052	70%	0.18
2028	70%	0.36	2053	70%	0.17
2029	70%	0.35	2054	70%	0.17
2030	70%	0.34	2055	70%	0.16
2031	70%	0.33	2056	70%	0.16
2032	70%	0.32	2057	70%	0.15
2033	70%	0.31	2058	70%	0.15
				Sum (2009-2058):	**15.56**

1. Values are discounted to 2006, the year for which injury DSAYs are calculated.

Attachment 3

HEA Inputs and Results for "Indirect" Restoration Benefits (John Heinz NWR)

Inputs:

Project Implementation	2009
Ecological Service Gain	10 percent
Years to maximum service	3
Curve for Service Gain	Linear
Project life span	50
Discount Rate[1]	3 percent

Results:

1 acre restored habitat provides 2.33 DSAYs of ecological service.

Annual Calculations:

Year	Ecological Service Improvement (per acre)	Discounted Ecological Service (per acre)	Year	Ecological Service Improvement (per acre)	Discounted Ecological Service (per acre)
2009	3%	0.03	2034	10%	0.04
2010	7%	0.06	2035	10%	0.04
2011	10%	0.09	2036	10%	0.04
2012	10%	0.08	2037	10%	0.04
2013	10%	0.08	2038	10%	0.04
2014	10%	0.08	2039	10%	0.04
2015	10%	0.08	2040	10%	0.04
2016	10%	0.07	2041	10%	0.04
2017	10%	0.07	2042	10%	0.03
2018	10%	0.07	2043	10%	0.03
2019	10%	0.07	2044	10%	0.03
2020	10%	0.07	2045	10%	0.03
2021	10%	0.06	2046	10%	0.03
2022	10%	0.06	2047	10%	0.03
2023	10%	0.06	2048	10%	0.03
2024	10%	0.06	2049	10%	0.03
2025	10%	0.06	2050	10%	0.03
2026	10%	0.06	2051	10%	0.03
2027	10%	0.05	2052	10%	0.03
2028	10%	0.05	2053	10%	0.02
2029	10%	0.05	2054	10%	0.02
2030	10%	0.05	2055	10%	0.02
2031	10%	0.05	2056	10%	0.02
2032	10%	0.05	2057	10%	0.02
2033	10%	0.05	2058	10%	0.02
				Sum (2009-2058):	**2.33**

1. Values are discounted to 2006, the year for which injury DSAYs are calculated.